Hole spin in silicon: from spin qubits to spin-photon interaction

Romain Maurand

CEA Grenoble-IRIG/Pheliqs, University Grenoble Alpes, 17 rue des Martyrs 38000 Grenoble, France

Romain.maurand@cea.fr

Semiconductor spin qubits based on spin-orbit states stand as promising candidates for quantum information processing. In particular, owing to the spin-orbit interaction (SOI) of valence states, hole spins in silicon and germanium are responsive to electric field excitations [1], allowing for practical and fast qubit control. This spin-electric response is intimately link to the complex and rich spin-orbit physics.
Here I will report on our last efforts leveraging spin-orbit interaction of hole spin in silicon devices produced on a semi-industrial 300mm CMOS foundry [2].
First, we demonstrated how SOI turns into an asset to engineer mixed spin-charge states in a double quantum dot (DQD) able to couple strongly with microwave photons. In an hybrid spin cQED platform, we revealed a hole spin-photon coupling of 300 MHz largely exceeding the combined spin-photon decoherence rate leading to a cooperativity above 1000 [3]. Moreover, we performed experiments showing that a qubit based on a single hole delocalized in a DQD can achieve high qubit quality factor [4]. With Rabi frequencies exceeding 100 MHz and coherence times in the microsecond range entirely limited by photonic effects, such qubit emerges as an interesting new candidate for quantum information processing and simulation based on hybrid spin circuit quantum electrodynamics.
Secondly, due to their spin-electric susceptibility, spin-orbit qubits may be vulnerable to electrical noise, which explains the relatively short coherence time reported so far. However, by varying the magnetic-field orientation, we experimentally established the existence of ``sweetlines" in the polar-azimuthal manifold where the qubit is insensitive to charge noise [5]. In agreement with recent predictions [6], we found that the observed sweetlines host the points of maximal driving efficiency. Furthermore, we demonstrated that moderate adjustments in gate voltages can significantly shift the sweetlines. This tunability allows multiple qubits to be simultaneously made insensitive to electrical noise [7].
All together, the coupling to microwave photon and the ability to hide from charge noise make hole spin in silicon an attractive platform to further develop semiconductor spin qubit-based quantum information processing.

References

[1] Golovach et al. PRB 74,1-19 (2006)
[2] Maurand et al. Nat. Com 7, 13575 (2016)
[3] Yu et al. Nat. Nano 18, 741-746 (2023)
[4] Noirot et al. unpublished
[5] Piot et al. Nat. Nano 17,1072 (2022)
[6] Michal et al. PRB 107, L041303 (2023)
[7] Bassi et al. arXiv :2412.13069 (2025)